CHEMICAL ENGINEERING TRANSACTIONS
VOL. 59, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Zhuo Yang, Junjie Ba, Jing Pan

ISBN 978-88-95608- 49-5; **ISSN** 2283-9216
DOI: 10.3303/CET1759045

Research on Interactive Design of Temperature Control System for Magnesium Alloy Melting Furnace Based on PLC

Wei Zong, Weipeng Niu*
School of Architecture and Design, China University of Mining and Technology, Xuzhou 221116, China
nwp2010@163.com

Based on the analysis of the whole system of magnesium alloy melting furnace, the functional requirements of the temperature control system are clarified. Based on the analysis of the melting process of magnesium alloy, the thermal stress situation in the heating furnace temperature rise period is analyzed by means of analysis of heat transfer simulation, the reasonable heating rate and magnesium melt temperature variation are determined. The method of control strategy based on PLC algorithm and multipoint temperature measuring are put forward to solve the temperature control system of magnesium melt temperature fluctuation in improper rate control and continuous casting. A set of control system based on PC and PLC is designed according to the functional requirements of magnesium alloy furnace temperature control system. The system uses PLC as the main control unit to realize the automatic heating control and data acquisition. At the same time, PC is taken as a human-computer interaction platform, and VB6.0 is used to develop computer monitoring software to realize on-line control of upper computer and lower computer and centralized control of the whole control system, which simplifies the operation, reduces the failure rate of the equipment, improve the work efficiency and the accuracy and flexibility of the system. The hardware configuration and software design of temperature control system for magnesium alloy melting furnace is completed, the temperature control system performance is tested, and the feasibility of heating system and the rationality that based on the duty ratio of hybrid control of output control and PID control are verified. According to the experimental results, the experimental system of magnesium alloy melting furnace is established, and the temperature control experiment is carried out. The experimental results show that the temperature control system achieves the expected control objectives.

1. Introduction

Magnesium alloys, as the lightest commercial metal structural materials, are widely used in the fields of automobile, motorcycle, information industry, aerospace and so on (Lopes, et al., 2017; Dong, 2016; Hou, 2016; Su, 2016). With the increase of the demand for magnesium alloy, the research and development of key production equipments such as magnesium alloy melting furnace and die casting machine have been paid more and more attention. At present, only a few developed countries have mature production technology equipment. Some domestic research institutions and enterprises realized the design and manufacture of magnesium alloy melting furnace, but compared with the foreign products, there are still significant gaps on the performance (Gesing, et al., 2016). Based on this background, this paper presents the research and development of magnesium alloy melting furnace temperature control system, which is based on the research and development of "the technology of green melting of magnesium alloy and the quantitative feeding furnace for melting and heat preservation" of Zhejiang province science and technology department.

2. Magnesium alloy furnace temperature control system

2.1 Temperature control system principle

The schematic diagram of the furnace temperature control system is shown in Figure 1.

Please cite this article as: Wei Zong, Weipeng Niu, 2017, Research on interactive design of temperature control system for magnesium alloy melting furnace based on plc, Chemical Engineering Transactions, 59, 265-270 DOI:10.3303/CET1759045

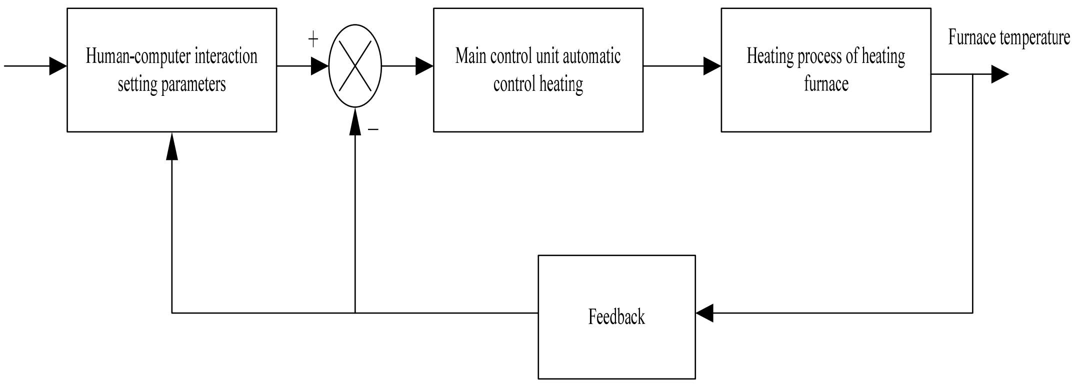

Figure 1: Schematic diagram of the furnace temperature control system

As can be seen from Figure 1, the furnace temperature is taken as the controlled object. The operator can use the man-machine interface to set a series of initial values, the control command can be transmit to the main control unit through communication. On the one hand, the temperature detection value of the furnace transferred by the temperature sensor can be received by the main control unit. On the other hand, the heating state of the heating element to the controlled furnace can be adjusted according to the control signal of the upper computer output to the intermediate controller, forming a closed-loop temperature control system and achieving the purpose of temperature control (Zhang, et al., 2016). In addition, the man-machine interface receives the data collected by the main control unit, which can monitor the whole control system.

2.2 Hardware functional requirements

According to the principle of temperature control system, the hardware system needs to realize the following functions:

①Human-computer interaction provides a platform for parameter setting and monitoring.

The temperature detection uses the temperature measuring element to realize the temperature.

②The temperature detection is used to realize the temperature detection and feedback to the control unit.

③The heating control output uses the main control unit to realize the automatic control of the heating actuating element, and realizes the data exchange with the man-machine interactive interface.

2.3 Software system

The purpose of software system is to realize the core control strategy and monitoring of the control system.
PLC working mode
Essentially, PLC (Cortés, et al, 2016) is an industrial computer control device which can extend input and output interface with the function of communication. Its working principle is based on the computer control system (Nguyen, et al, 2016) that is completed through the user program by carrying out the control requirements. But CPU deal with the tasks in a time-sharing operation mode. Each computer can just do one thing in every moment, so the program is executed according to the procedure that completing the corresponding electrical action in order, so it belongs to the serial working mode.
The main working process of PLC can be divided into 4 basic steps: public processing, input sampling, executing program and output refresh (Qian, et al, 2016).
In addition, the program provides the user with internal relays, timers, counters and other soft components. It has the characteristics of the relay, nut does not have the mechanical contacts. The contacts can be unlimited referred, and not limited by the service life. These software components provide a great convenience for the debugging and maintenance of the program, and create the conditions for the normalization of the program design.

2.4 Control strategy

Intelligent temperature control module Q64TCTT provides users with PID control and direct duty cycle output control two control methods (Xin, et al, 2016) Among them, the PID control has been more mature in the PLC technology, but it involves temperature sampling, PID calculation, PID parameter setting and other issues (Ye, et al, 2017) especially the setting of PID parameters is relatively difficult. But the direct duty cycle output control method is simple, only needs to set the cycle and the duty according to the user demand, but often its control precision is not high. In this paper, according to the actual needs, the appropriate control strategy will be determined by the following experiments.

2.5 Man-machine interface

The man-machine interface of the system needs to meet the following requirements

① The operation interface is simple, and conforms to the production process. It is convenient for users to operate.

② Security password protection. It can prevent workers from operating errors. The password should be set for the important parameters.

③ Simple man-machine interactive operation. According to the requirements of the operating conditions, the operator issues control commands from the man-machine interface, which will be transferred to PLC to carry out the specific operations after going through the PC and PLC communication.

④ Real time monitoring and data analysis. The temperature and alarm in the melting process of magnesium alloy should be displayed and recorded in real-time, and the historical temperature data should be checked.

⑤ According to the needs of the user, the sampling frequency, temperature preset parameters, and the manual and automatic switching operation should be set.

3. Experimental study on temperature control of melting magnesium in magnesium alloy melting furnace

The experimental system is built, and the temperature control system and the control strategy of heating and melting stage are verified.

3.1 Magnesium melting experiment system

The heating system, the structure of the furnace and the thermal insulation layer are improved.
In addition, according to the process requirements of the magnesium alloy smelting furnace, the N_2 and SF_6 mixed gas are prepared to protect system, as well as the quantitative pouring system.

3.2 Magnesium melting and heating experiment

3.2.1 Experimental target

According to the progress of the project, under the condition that the gas protection system is not perfect, the magnesium alloy AZ91D is used as the medium to carry out the heating experiment of the magnesium alloy furnace. Combined with ideal temperature control curve in heating and melting stage in the second chapter, the control objective is required to achieve as shown in Table 1. Among them, the furnace heating stage is based on the furnace temperature control, so the following temperature rate and the sampling data involved in the article take the main furnace temperature control point data as the criterion, no longer described below.

Table 1: Technical requirements for temperature control of magnesium alloys

Parameter	Objective value	Average heating rate	Insulation precision
Technical requirements	450	60~80	≤±5

3.2.2 Experimental scheme

The hybrid control of direct duty cycle output control and PID control is used. In the range of 20 °C--30 °C at room temperature, the temperature control is realized by controlling the duty cycle output of the two chamber heating control loop. In the range of 300 °C--450 °C, the PID is used to control the average heating rate and the final steady state heat preservation precision.The settings of the subsection in early stage of duty cycle control and the duty cycle in each stage are estimated according to the power system and quality of magnesium ingot, and then adjusted gradually in order to ensure the temperature difference between the two points for measuring temperature is as small as possible before entering the PID control stage. After determining the initial duty cycle, the PID control parameters are adjusted. The setting of the PID parameter has a certain regularity, but it needs to observe the change of the response curve, and constantly modify the parameters when adjust the parameters. Satisfactory control curve can be obtained after several tests.

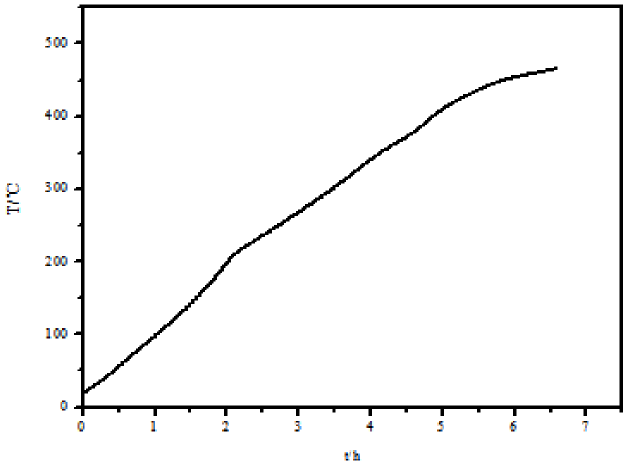

Figure 2: Temperature sampling curve of PI control in the heating phase of magnesium smelting

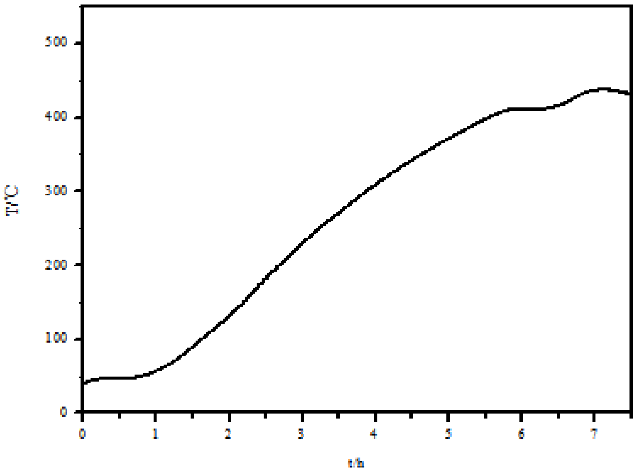

Figure 3: Temperature sampling curve of PID in the heating phase of magnesium smelting

In this paper, when setting the PID parameters, the temperature sampling curve of the main temperature control point of the partial heating furnace is obtained, as shown in Figure 2 and 3. Figure 2 is the overshoot temperature curve obtained by PI control. On the basis of the PI control shown in Figure 2, the temperature curve of Figure 3 is obtained by adding D control. Although the result of Figure 3 is still not ideal, it can be seen that the result is gradually improving in the process of revising the parameters.
The parameters obtained by multiple tests are shown in Table 2.

Table 2: Temperature control strategy

Temperature stage		20~100	100~300	300~450
Control method		Duty ratio output	Duty ratio output	PID
Set value	Melting chamber	60%	100%	K_p=60%, T_1=240, T_D=50
	Insulation room	80%	100%	K_p=80%, T_1=240, T_D=60

Note: the sampling time T_S in Q64TCTT temperature control module is fixed, and it doesn't need the user to set.

3.2.3 Experimental results

According to the control strategy in Table 2, the temperature rising of magnesium is tested. The VB monitoring system of the host computer collects the data every 5 seconds, and the temperature rising curve of magnesium alloy is shown in Figure 4.

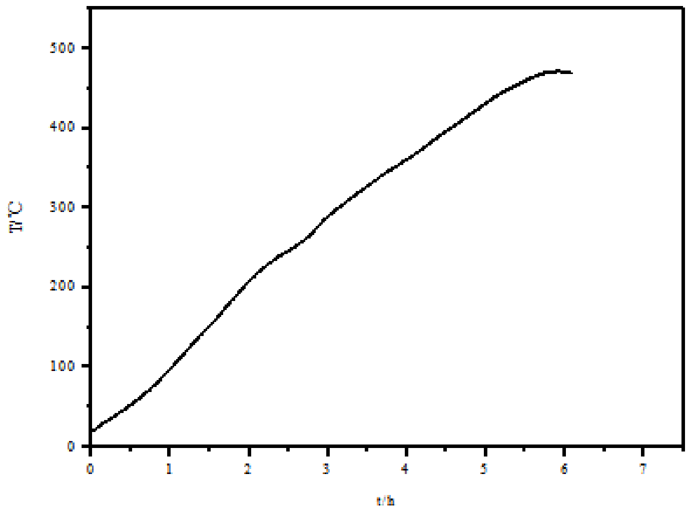

Figure 4: Temperature sampling curve of magnesium alloy temperature control

According to the temperature sampling curve, it is found that the heating temperature of magnesium alloy melting furnace is stable, and the average heating rate is kept at 70~80°C/h. After nearly 6 hours of heating, the temperature of magnesium alloy has reached to 450°C, and entered the stage of heat preservation, the final temperature control accuracy remains within the range of ≤±5. However, it should be noted that the PID parameters given in Table 2 are not unique, because the influence of PID parameters on the control effect is correlative, that is to say, the other PID parameters can also achieve the same control effect.
The experimental data show that the temperature control system adopts the hybrid control strategy of direct duty cycle output control and PID control, and realizes the experimental target.

3.3 Summary

According to the results of the experiment, the experimental system of magnesium alloy is improved. According to the requirements of the project, the feasibility of the temperature control system and the control strategy is verified by the temperature control experiment. The experimental results show that the control strategy of the temperature control system using direct duty cycle output and PID hybrid control has the ability to realize the stable temperature control of magnesium alloy, which can achieve the goal of the project

4. Conclusion

The magnesium alloy material has the unique advantages and is widely used in various fields, such as automobile, motorcycle and information industry. With the increasing demand on magnesium alloy, people vigorously develop the magnesium alloy production equipment. The domestic research and development of magnesium alloy manufacturing equipment is relatively backward, its application is relatively little. In this paper, through the research of temperature control system for magnesium alloy melting furnace, the application of the temperature control system in magnesium alloy furnace is realized, which promotes the developing of magnesium alloy technology, and promotes the development of China's magnesium alloy industry. In this paper, the research and development of magnesium alloy furnace temperature control system mainly completed the following work:

Reference

Cortés J.A., Sanz A., Estopiñán P., García J.I., 2016, March, Performance assessment of OFDM-based narrowband PLC for advanced metering infrastructure. In Power Line Communications and its Applications (ISPLC), 2016 International Symposium, 132-137, IEEE.

Dong S.W., 2016, Study on modification of novel magnesium alloy for sports equipment, Chemical Engineering Transactions, 51, 241-246, DOI: 10.3303/CET1651041
Gesing A.J., Das S.K., Loutfy R.O., 2016, Production of Magnesium and Aluminum-Magnesium Alloys from Recycled Secondary Aluminum Scrap Melts. JOM, 68(2), 585-592.
Hou Z.K., 2016, The effect of casting method on fatigue property magnesium alloy used in sports apparatus, Chemical Engineering Transactions, 51, 283-288, DOI: 10.3303/CET1651048
Lopes V., Pereira J., Carneiro V.H., Puga H., 2017, February, Magnesium alloy biodegradable scaffolds: Simulation of casting and manufacturing. In Bioengineering (ENBENG), IEEE 5th Portuguese Meeting, 1-4, IEEE.
Nguyen B.K., McNally G., Clarke A., 2016, Automatic extruder for processing recycled polymers with ultrasound and temperature control system. Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 230(5), 355-370.
Qian X., Li R., Cao Y., Ni Y., Wu X., 2016, Modelling CF of tobacco industry based on PLC across the supply chain. International Journal of Service and Computing Oriented Manufacturing, 2(3-4), 258-276.
Su Z., 2016, Chemical analysis of the mechanical properties of aluminum magnesium alloy badminton racket under heat treatment, Chemical Engineering Transactions, 55, 247-252, DOI: 10.3303/CET1655042
Xin Y., Sun L.X., Yang Z.J., Zeng P., Cong Z.B., Qi L. F., 2016, In situ analysis of magnesium alloy using a standoff and double-pulse laser-induced breakdown spectroscopy system. Frontiers of Physics, 11(5), 115207.
Ye H., Wang Z., Wang L., 2017, Effects of PCM on power consumption and temperature control performance of a thermal control system subject to periodic ambient conditions. Applied Energy, 190, 213-221.
Zhang L., Zhou W., Hu P., Zhou Q., 2016, Effect of Al-3Nb-1B Master Alloy on the Grain Refinement of AZ91D Magnesium Alloy. Metallurgical and Materials Transactions B, 47(3), 1999-2004.